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ABSTRACT

The purpose of this study was to investigate the process used by learners to direct, locate, and integrate information resources for use in a project-based environment. Four cases (n=9, including three group projects and one individual project) were analyzed from an introductory educational technology course for preservice teachers during a unit on telecommunications. Participants were asked to generate projects for integrating the Internet into the curriculum. Within this project-based context, learners searched for information resources that would accompany their project ideas. Specifically, the study examined: strategies used by participants to guide their information seeking; the role of system, domain, and metacognitive knowledge in locating World Wide Web resources; and the extent to which student integrate Web resources into coherent projects. Three major findings related to use of hypermedia systems during project-based learning are discussed: (1) progressing from data-driven to goal-driven approaches was critical to developing a coherent project idea: (2) consolidating multiple information resources with proposed project methods and rationales was challenging for learners; and (3) metacognitive, domain, and system knowledge appear critical to achieving coherence in project development. Implications related to the role of instructional scaffolding in encouraging goal-driven and metacognitive processing during open-ended learning are considered. (Author/MES)

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Project-Based Learning with the World Wide Web: A Qualitative Study of Resource Integration

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Abstract

The purpose of this study was to investigate the process used by learners to direct, locate, and integrate information resources for use in a project-based environment. Four cases (N=9) were analyzed from an introductory educational technology course during a unit on telecommunications. Participants were asked to generate projects for integrating the Internet into the curriculum. Within this project-based context, learners searched for information resources that would accompany their project ideas. Three major findings related to use of hypermedia systems during project-based learning were discussed: (a) progressing from data-driven to goal-driven approaches were critical to developing a coherent project idea; (b) consolidating multiple information resources with proposed project methods and rationales was challenging for learners; and (c) metacognitive, domain, and system knowledge appear critical to achieving coherence in project development. Implications related to the role of instructional scaffolding in encouraging goal-driven and metacognitive processing during open-ended learning are considered.

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Introduction

In the information age, it has become increasingly important for students to learn how to identify information needs, locate corresponding information resources, and integrate information from a variety of sources into cogent, productive uses (Moore, 1995). Such requirements represent radically different cognitive goals than are typically fostered in traditional classrooms – goals exemplified by teacher-centered or instruction-centered interactions that prescribe responses from learners. Externally-centered instructional methods, according to critics, fail to support meaningful generation of understanding (Jonassen, 1991) and fail to address the knowledge requirements of a rapidly expanding technological society (Hannafin & Land, 1997).

Yet, recently, much attention has been dedicated to diverse applications of technology that support active, student-centered learning. Contemporary theoretical perspectives have emerged that emphasize the centrality of the learner in exploring, manipulating, and generating understanding (Cognition and Technology Group at Vanderbilt, 1990; Spiro, Feltovich, Jacobson, & Coulson, 1991). Open-ended learning environments (OELEs) are learner-centered environments that facilitate the unique efforts of learners to generate and refine meaning (Hannafin, Hall, Land, & Hill, 1994). They represent a variety of approaches and technologies that enable learners to engage cognitively complex tasks that require critical thinking, self-direction, problem-solving, or meaningful integration of knowledge (Land & Hannafin, 1996).

Project-based learning is an approach to open-ended learning that encourages meaningful learning through student-directed investigation (Blumenfeld, Soloway, Marx, Krajcik, Guzdial, & Palincsar, 1991). Students pursue solutions to open-ended problems by formulating questions for investigation, designing plans or proposals, collecting and analyzing information, and creating "artifacts" or products of their understanding (Blumenfeld et al., 1991). Project-based approaches satisfy two primary components: (a) learners generate a question or problem that serves to organize and drive learning needs; and (b) learners produce a final product or series of products to address the driving question/problem derived (Blumenfeld et al., 1991). Through extended investigation and experience with the problems under study, learners are presumed to identify knowledge needs, locate required resources to help them meet these needs, and integrate diverse information into coherent explanations or projects.

With project-based approaches, information resources, such as the World Wide Web, can play a critical role in the learning environment. In the process of working on projects, students require access to information. As students generate learning goals or problems, they seek new information when they find themselves unable to proceed without deepening understanding of what is already known (cf., Moore, 1995). Identifying and generating a "need to know" is assumed critical for meaningful integration of information. Organizing frameworks, such as student-generated problems or questions, are required for learners to focus, verify, and generate cohesion to the information retrieved (Hill & Hannafin, 1997; Moore, 1995).

Simply providing access to information does not guarantee if will be useful to students in generating and refining projects. That is, students might search vast databases of information, but fail to *use* this information to solve problems or deepen understanding. The process would be similar to searching for information with no purpose, intent, or reason. Without generating driving questions or learning goals, it is unlikely that retrieved information

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would be meaningful to learners, since it would be isolated from a meaningful context (cf., Brown, Collins, & Duguid, 1988).

Yet, the process whereby learners generate information needs, search information resources, and integrate varied resources into a cohesive project is little understood. What is known, suggests that learners' level of processing is often poorly matched to the processing needs of information-rich OELEs. For example, previous research on student learning with OELEs indicates that learners often have difficulty generating unique learning goals and, instead, rely heavily upon external guidance to direct their activity (Land & Hannafin, 1997; Oliver, 1999). Furthermore, studies of learner use of the World Wide Web have indicated that students frequently fail to establish or alter task-relevant goals, and they show little evidence of engaging meaningful, reflective activity (Hill and Hannafin, 1997). Individual knowledge variables, such as metacognition, system knowledge, and prior domain knowledge have been shown to influence the extent to which learners productively seek, locate, and integrate information resources (Hill & Hannafin, 1997). Qualitative studies of children's use of information retrieval systems during project-based learning show that students often (a) fail to generate questions that extend from what is known; (b) are ineffective in using search terms; and (c) process accessed information as "answers," rather than as data for reflection and evaluation (Moore, 1995; Wallace & Kupperman, 1997).

Accordingly, the purpose of this research was to investigate the process used by learners to guide, locate, and integrate information resources for use in a project-based environment. Addressing this purpose requires insight into the unique intentions, actions, and sense-making processes of learners though out the learning process. The goals of this research were primarily descriptive in nature and were aimed at gaining a deeper understanding of the problems and processes experienced by learners in this endeavor.

The study examined the following questions:

1. What general strategies do participants use to guide their information seeking?
2. What is the role of system, domain, and metacognitive knowledge in locating web resources?
3. To what extent do students integrate web resources into a coherent project?

Method

Nine undergraduate pre-service teachers participated in the study. The participants were primarily attaining certification in early childhood and elementary education, although three were pursuing secondary English certification. They were enrolled in a required course, "Learning with Educational Technologies," and were awarded extra credit for participating in the study. Students were asked to generate project ideas for an instructional planning activity to integrate the Internet into the classroom. Within this project-based context, learners searched for information resources that would accompany their project ideas. The participants elected whether to work as groups or by themselves for the project. The groups and/or individuals were studied as separate cases and analyzed for similarities and differences by referencing an existing theory-based pattern (Yin, 1994).

Three primary techniques were used for data collection: Think-aloud protocols, videotaped observations of system use, and student-generated documentation (i.e., final project documentation and history lists of web usage). Data collection lasted four consecutive days. Each class period lasted approximately 2.5 hours. All interactions were videotaped, with the camera recording activities on the screen and audio recording student conversations. The instructor and another co-investigator were present during all class periods and continually circulated among the students to facilitate their learning.

Think-aloud protocols and observations of videotaped system events yielded foundation data for the analysis. Think-aloud protocols were transcribed and matched to videotaped observations of learner actions with the web. Data were collated according to each of three pre-defined research questions: Strategy use, information location, and coherence of project ideas (see for example, Merriam, 1988). Criteria were developed for each question, which were used to assign data (see Lincoln & Guba, 1985). For instance, isolated responses such as "maybe I should try another search engine," or "I need to find something on public schools on the web" were labeled as individual units (Ericsson & Simon, 1992). Both authors coded the data in order to achieve 100% agreement on the codes.

Findings and Implications

Question 1: General Strategies Associated with Information Seeking

This question examined the strategies used by participants to identify knowledge deficiencies, set learning goals, and seek information using the World Wide Web to generate and refine project ideas. Each protocol was coded for evidence of two categories of strategies:

1. data-driven strategies,
2. goal-driven strategies (adapted from Hmelo, in press)

Category 1: Data-driven strategies. Data-driven strategies involved inferring from the data (i.e., web resources) to possible project ideas or explanations for use of that data. Using this approach, participants identified broad subject areas, conducted a search, read information on the topic, and formulated ideas and questions *from* the web resources. During initial stages of project planning, all participants used data-driven strategies to explore possibilities for ideas. These strategies were most readily apparent in instances where participants conducted a search on a general topic (e.g., the state of California) and accessed a number of possible links from a given page (e.g., tourism in California) or list of search results. They would then "browse" the sites that appeared interesting in order to evaluate their usefulness. Janie, for instance, conducted a search to find sites affiliated with grocery stores for her project idea. She stated, "Let's see if something about grocery stores is listed...[finds Groceries On-line link] Let's find out about this website." She read the information, returned to the retrieved search list, and began exploring other grocery store links such as Food Lion and Shaw Supermarkets. The function of these searches was to focus ideas and to "see what is out there" before committing to a specific project idea.

Data-driven approaches were marked by interpretations of the significance of isolated data (e.g., a specific site accessed) independent of pre-defined and specific contexts for using them. Such approaches did not require deliberate search strategies as a means for finding information. Rather, participants identified broad topics, used general search terms (e.g., "travel", "groceries", "Shakespeare") viewed "hit lists" of retrieved sites, and browsed through the sites in an effort to find ones that could be used for the project idea. Janie, for instance, would often browse through long lists of links, without specifying what she was trying to accomplish: "OK, I'm getting to the end of the list of 366 sites. And it's always the last page ... that has the information you're looking for..."

Participants who relied heavily on this approach characteristically sorted through many irrelevant sources that ultimately had little to no bearing on developing project ideas; instead, they engaged in tangential inquiry of web resources without a clear "anchor" or context for directing the search task. While data-driven reasoning was common among all cases during initial stages of project formulation, two cases relied heavily upon data-driven strategies throughout the entire project (Case 3: Janie, and Case 4: [Desi, Nell, and Opal]). Their reliance on external data as the driving force for ideas often led to problems in locating information and in discerning how information could be useful. In turn, this often led to frustration, inefficiency in information retrieval, and the use of frequent statements such as "We're just not finding anything."

Yet, use of data-driven strategies sometimes resulted in serendipitous findings that led the participants in new directions for their project ideas. For instance, when browsing the EduStock site, Kara and Tammy found a stock market simulator that enabled real-time, simulated buying and selling of stocks. They incorporated this feature into their project idea, which prior to finding this site, was more vague and disconnected ("We're going to do something with the stock market"). Similarly, Tammy noted that the stock market is in the process of converting from decimals to fractions. She noted, "We can integrate more math skills, since the kids will need to convert." Their project ideas were formulated and expanded based upon the identification of resources and tools that they did not intentionally access for use in the project.

Similarly, when Janie was browsing grocery store sites for cost comparison data, she found a link to a supermarket chain in Hong Kong. She said, "a Web site from Hong Kong I can go grocery shopping on. So, we get to expand our project to include different countries. . . it has its prices in their currency. Boy my kids are going to have to do some big time conversions." In both of these examples, the participants had not previously considered these ideas, and they were able to identify resources and consider alternatives for using them. Use of data-driven strategies led to expansion of possibilities for the web project, in that the search space was not constrained by requirements for specific forms, or purposes, of data.

Category 2: Goal-driven strategies. With goal-driven approaches, participants sought information in the context of a goal, hypothesis, or question. Such strategies required a judgment regarding what information was desired, prior to knowing what information was available. When searching, participants considered the kinds of web resources that were needed, bearing in mind both the project focus and resource needs, rather than collecting isolated sets of web resources. Goals for information-seeking were inextricably tied to learner hypotheses and/or "needs to know" for the project idea. A major function was validating or testing the viability of project ideas.

Goal-driven approaches represented strategic, directed intentions to access specific sites or information. The purpose of these goals was to confirm that specific information was accessible in order to apply it to the project idea. These strategies were most obvious in cases where the learner(s) were looking for a specific site or piece of information. To illustrate, Case 1 participants proposed a project for elementary students to learn geography by planning a virtual vacation. They identified the State of California as a possible place to visit. Accordingly, Jill suggested, "Let's see if we can get a Disneyland [site] to come up. Because if we can't find it, the kids won't be able to access it." They continued these types of directed searches for airline and rental car prices, gasoline prices, maps of the areas, and so on. The purpose of these searches was to determine whether or not the idea was viable using web resources. If they were unable to access the information and/or find it useful, it was unlikely that their students would benefit from the activity. Finding and validating the usefulness of specific sites or ideas assisted participants in expanding or filling in the details of their project ideas.

Use of goal-driven strategies required a focus that helped participants to limit the search space and to filter relevant from irrelevant information. When participants approached the search task from the perspective of confirming a hypothesis, they were able to apply the retrieved information to solve a problem that was relevant to their project idea. For instance, Case 1 (Jack, Jane, & Jill) were looking for sites that their students could use to plan and budget a virtual family vacation. Jane commented, "We also have to figure out gas prices. It's got to be more expensive at different [geographic] locations." Formulating this hypothesis led the group to investigate gasoline prices in different states across the United States. The information retrieved was then useful for helping them to evaluate their project focus and consider the problem stipulations that would be relevant to their future students.

Similarly, Case 2 (Tammy and Kara) considered a project idea for their students to use on-line, simulated investment portfolios as a means to pay for college. When looking for information on tuition costs at the University of Oklahoma website, Tammy noted: "This tells us all of the fees per/credit hour. So, an Ivy League school would cost a lot more. We could [look up cost information for different schools] and give them a choice between attending a community college, OU, or an [Ivy League] School." Following up on this hypothesis about differential cost structures enabled them to find information that established another dimension of complexity to their project. When search strategies were driven by hypotheses, the accessed information did not remain isolated and discrete; rather, it was situated within an applied context (Brown et al., 1988); in this case, the project context that was generated by the participants.

Question 2: Knowledge Sources for Retrieving Information from the WWW

Question one examined the general strategies used by participants to define the information they wanted to retrieve from the Web for use in the project. Question two extends from this question to examine how successful participants were in actually *retrieving* or locating this information. Three sources of knowledge influence successful retrieval of information: (1) system knowledge (and use of search terms); (2) the role of domain knowledge in locating information; and (3) metacognitive knowledge of how to monitor and revise search techniques (Hill & Hannafin, 1997). It is important to note that all three categories of system, metacognitive, and domain knowledge operate simultaneously to influence successful retrieval of information. Yet, for the purposes of distinguishing their respective influences, they will be treated separately in the reporting of results.

System knowledge. Participants typically retrieved information from the web by using search engines, search engine indexes, and/or known URLs that were typed into the "go to" field. When participants were already aware of sites or features available on the Web, they were successful in locating them and assigning a use for them in the project. For instance, Jack from Case 1 [trip-planning topic], was already aware of many sites on the Web that could be useful for their project. He noted, "There is a deal on Yahoo that can help you make maps. We can have the students use this to make maps of where they will go. [The map tool on Yahoo] will tell them how long it will take to [travel to their destination] and will help keep them realistic." In this instance, awareness of features available on the web and a purpose for how they could be used helped Case 1 successfully locate needed resources for their project.

Whereas system knowledge of how to use these search features was critical for locating information, it was also clear that the way in which questions were asked influenced the search terms defined which influenced subsequent retrieval. For example, Janie, who reported to be an experienced Web user, continued to use vague, broad search terms like "schools" and "web". When she encountered hundreds of retrieved sites, she proceeded to systematically browse through all the abstracts related to those sites, stating that the best one will surely be found on the last page of abstracts. Standard Boolean operators were not typically used by Janie to refine or narrow the scope of a search. Consequently, she frequently reported being frustrated at failing to find useful sites. In one critical instance, Janie neglected to use the bookmark feature to store sites of interest to her. When she wanted to return to these sites on the second day, she spent almost 2 hours searching for them (unsuccessfully).

Case 4 (Desi, Nell, and Opal) experienced similar difficulties with identifying and using focused search terms. In one interaction, Desi remarked: "We're trying to find information on history. I'm trying to think of how we could...word it. Because we're not wanting what happened to Shakespeare, we're wanting what happened in general history, right? Just try searching for "16th century."

The vague nature of the search terms used by Case 4 was common throughout their web searching. Consequently, they found little information of use to them and frequently remarked they nothing was available on the web on "history." Throughout the entire period in which they worked on the project, Case 4 failed to delineate the aspects of Shakespeare's life or works that would be the focus of the project. Nor did they define a specific historical event or artistic influence that was considered relevant to his writing. Consequently, they used equally ambiguous search terms such as "17th century" or "Shakespeare history" in an effort to retrieve poorly specified information.

Domain knowledge of the topic under investigation. Learner domain knowledge has been found to be a critical factor for both developing instructional contexts and for locating information in hypermedia information systems (Hill & Hannafin, 1997). Making meaning from new knowledge is largely influenced by the extent to which it is connected to existing knowledge (Brown, Bransford, Ferrara, & Campione, 1983). In this study, we

found that limitations in domain knowledge were difficult to overcome in an ill-structured information system where inquiry-based searches were required. To illustrate, many of the problems experienced by Case 4 in finding information seemed to be driven by a lack of domain knowledge about the time period and historical events associated with Shakespeare's writing. In some instances, their questions were based on misunderstandings or inaccurate subject knowledge, and they were often unaware of such misunderstandings. This led to a snowball effect of frustrations, since they then had difficulty finding information and failed to consider that their initial assumptions were inaccurate.

In other instances, however, Case 4 occasionally found (and learned about) information that triggered awareness of their misunderstandings. For instance, after two days of unsuccessful browsing about history and Shakespeare, they stumbled upon a site that provided information regarding the reign of Elizabeth I. Nell noted, "If we look up Elizabeth I, that would tell us the history there, and what was going on when he was [in England] because it says that his writing got gloomier during that time."

Similarly, Case 4 had misunderstandings regarding the time period in which Shakespeare was writing, and consequently used inaccurate search terms. During day 2, the group searched for historical information on the Middle Ages. Later, they saw a title on a search index entitled "The Renaissance and the Globe Theater". Nell noted, "Renaissance! That is why all of this Middle Ages stuff was not coming up. So let's look up Renaissance now." These instances illustrate how lack of domain knowledge seriously hindered the extent to which participants could productively find relevant information on the Web. However, it also appears that participants *can* use an information system such as the Web to recognize limitations in knowledge and to use what is learned as the basis for further investigation.

In contrast, Case 1 experienced few problems with locating relevant information. We believe that this was due, in part, to the fact that all members of this group had well-established schemata for trip planning and were thus able to draw upon this knowledge to ask questions and use search terms effectively. For instance, Jack commented, "We haven't looked at [websites] for airline tickets and car rentals. Go to Hertz.com." Later, they used the Yahoo Travelocity site for students to investigate prices for airline reservations. In this instance, prior knowledge and experience with trip planning (as well as system knowledge of what was available at Yahoo and the Hertz car rental home page) made locating relevant information productive for this group. Prior domain knowledge, then, was critical for identifying a "need to know" and for then using search terms and indexes to retrieve the needed information.

Metacognitive Knowledge. Metacognitive knowledge is often characterized as consisting of three interrelated components: (a) awareness of one's own cognition and the degree to which one's cognitive efforts are successful; (b) knowledge about the different cognitive demands of different learning tasks, and (c) procedural knowledge of strategies to employ when the status quo is not successful (Garner and Alexander, 1987; Moore, 1995). In the context of our study, metacognitive knowledge refers to the process of reflecting on, or monitoring the effectiveness of the search process and then refining the process when necessary. Previous research on use of the World Wide Web found that metacognitive knowledge was critical for participants "to reflect on their search processes, refine their actions, and make better use of the system" (Hill & Hannafin, 1997, p. 56). Participants with low metacognitive knowledge often used unproductive search strategies and failed to monitor and alter those strategies when necessary (Hill & Hannafin, 1997).

All four of our cases demonstrated some reflection and monitoring. At some point, the participants in each case reflected on the effectiveness of their search strategies; in three of the cases, the participants acknowledged that their search efforts were not fruitful. However, as we discuss below, our data demonstrate that awareness alone does not constitute a sufficient condition for metacognitive knowledge. The role of learner metacognitive knowledge in locating desired resources was apparent in instances where participants refined search terms and strategies when needed. Case 1, for instance, often evaluated the limitations of the accessed information and re-focused their search efforts to narrow the type of information retrieved. Using the WWW to effectively locate information requires key components of metacognition -- continual monitoring of learning activities and goals, and an awareness of instances when plans are inconsistent with outcomes.

Case 2 (Tammy and Kara) also relied on metacognition to re-direct the search process. While searching for performance data on the company Kimberly Clark from the EduStock site, they found a website that they initially hoped would provide this information. Instead, the website was irrelevant for their project. Tammy noted, "This website gives me a ton of stuff. But, I want [a web page about] the company Kimberly Clark. I'm sure they have their own web page." She then revised her search, using a Yahoo index and found the home page for the company.

Effective location of information from the WWW seems to require the following: (a) awareness of the form and purpose of information desired; (b) awareness of whether the accessed information matches the desired information (i.e., filter relevant from irrelevant information); and (c) awareness of how to refine search terms and strategies in order to produce effective results. Not all participants used these processes, however, and those who did not experienced difficulties in accessing desired information. For instance, Case 4 was searching for poorly specified information for their Shakespeare project (i.e., world events associated with the time of his writing). When

they recognized that the information accessed did not match what they wanted, they failed to refine either their search goals or their search strategies. Their main problem seemed to be that they never identified what information they actually wanted. Without clear criteria for relevancy, they were unable to effectively sort through what they found. They repeatedly entered the same search terms, often switching search engines, with equally unproductive results. In most instances, changing search engines appeared to be an ineffective strategy for refining a search. The failure of some participants to recognize the ineffective outcomes of this strategy seemed often to be related to inadequate system knowledge. They did not know what else they could do when their known and preferred strategies were limited.

For Case 4, the failure to demonstrate metacognitive knowledge concerning search results seemed explained by inadequate domain knowledge, in addition to insufficient system knowledge. In fact, based on three of our cases, we might infer that effective metacognition depends on adequate knowledge in the other two areas. For example, the two cases that seemed to demonstrate low metacognitive knowledge, Case 3 (Janie) and 4 (Opal, Nell and Desi), were also cases in which other knowledge was low and the goal for searching remained ill defined. Case 1 demonstrated high metacognitive knowledge and also demonstrated high system and domain knowledge. By contrast, however, Case 2 (Tammy and Kara) also demonstrated high metacognitive knowledge but had only novice level system knowledge and low domain knowledge (their domain was the stock market). What seemed to separate Case 2 from both Case 3 and 4 was their continual monitoring of the search process in light of their evolving goal. The following exchange captures how they engaged in this process.

> Tammy: This is forecasting college costs. They can come to this site.
> Kara: So are we still doing the stock thing? Incorporating both or changing?
> Tammy: This is why they are doing the stock market. You need to go to college and figure out how much it costs you, you need to go out and figure how to invest to make this much money so you can plan for college.
> Kara: That's a good idea; point for making money. That makes sense.

For Case 2, metacognition was seemingly able to compensate for low domain and moderate system knowledge. For Cases 3 and 4, the benefits of their metacognitive processing seemed to be limited by the absence of well-defined project ideas or even search goals. Although they engaged in some reflection and monitoring, they lacked clear criteria for relevancy through out the project. Therefore, their monitoring attempts resulted in frustration rather than progress.

Question 3: Evidence for Developing Coherence

The third question provides a means for summarizing the efforts of the four groups in terms of the integration of their project ideas and search results into a coherent project. We defined coherence as the extent to which project methods and resources were consistent with stated purposes. We approached this question in two ways. First, we examined the protocol data for instances of cohesion or processing that suggested the projects were headed toward cohesion. Then, we examined the project write-ups for evidence of coherence.

The examination of the protocol data revealed two broad categories: fragmentation and consolidation. Fragmentation occurred when participants failed to evaluate the usefulness of web resources in light of their project idea. So, when participants were engaged in data-driven searches, fragmentation was common. As the project developed, and searching became more goal driven, most participants consolidated their ideas *and* web resources into a functionally bound instructional activity. This process involved a discarding and evolving of ideas that could be actualized using identified web resources. Participants went through several iterations of integrating ideas and accessed web sites in an attempt to stabilize the overall project idea. The process required them to step back and integrate the activity that will be posed to their students, clarify the reasons for their decisions, evaluate them in light of project requirements, and determine how use of the web fits into the process. This was a difficult process for all cases and, as a result, they all occasionally experienced frustration and confusion. Although all cases achieved some level of consolidation, both cases 3 and 4 were less successful than 1 and 2, and showed more evidence of fragmentation than coherency.

Persistent Fragmentation. Janie (Case 3) began with an idea about having students (grades 2 or 3) research local prices of groceries and compare them with prices in different areas of the country (later she expanded to other countries, but went back to just the US in her final project). As she began exploring the web, she realized she could structure the activity in several ways: (1) by asking students to use on-line advertisements for grocery prices for different areas of the country; (2) by having students communicate via e-mail with other students in different parts of the country regarding grocery prices; and (3) by using tools such as cost of living comparisons to help explain the reasons for the differences. While using the Web, she focused almost exclusively on one alternative at a time: finding sites for collaboration with schools *or* finding sites for cost of living comparisons *or* finding on-line grocery sites. Fitting the pieces together was challenging for Janie, and she seldom stepped back to grapple with the whole picture.

Janie's write-up of her project reflected her fragmentation. She first stated that the objective of her project was for students to find out the cost of foods around the country and why the costs are so different. However, she later stated, "I really don't know how to give them an answer to "why?" but only to allow them to understand and realize that not all things are the same as where they live." In other words, she never quite integrated her project ideas. Her Web resources included: (a) e-mail contacts with classes around the country; (b) sites for looking up prices for favorite foods around the country; and (c) several sites for cost of living comparisons. The relationships between these three resources were never made clear.

Case 4 also demonstrated many instances of fragmentation. Desi et al. spent most of their time inefficiently searching for sites on the art and history associated with the time period when Shakespeare was writing. When they found a site on Renaissance Fair Garb, Nell noted, "Perfect. So each group is going to specialize in an area. They will each have to come up with a costume. Everyone will dress up and bring food..." Desi replied, "Now I'm confused. I thought it was going to be about what would make Shakespeare more understandable to them." Nell, "well, they will have to study a passage anyway, so have them perform it. They will already be dressed up."

After two days of searching for world events and art associated with Shakespeare's time, Nell noted, "Why don't we just [change] our project. They don't necessarily need to know the art. Art had no influence on history. Art didn't really influence Shakespeare." Desi interrupted, and requested that they change the focus, "[our students] will have to read Beowulf. So, let's go for it." Opal asked, "So what is our point with Beowulf?" Desi replied, "we want them to understand the culture. It's a hunter and gatherer kind of society." Nell said, "We can just change everything we have for Shakespeare and apply it to Beowulf. To understand it, you also have to have an overall comprehension of the culture." After further discussion, Opal finally suggested a move toward consolidation, "let's just scrap all of that and focus on the comprehension of the play itself. We found all of those sites that break down the language and they can go into those chatrooms and discuss with those other people the questions they have about the play, and see if they can find out through those rooms and e-mails, the perspectives of other people and their interpretations of the play."

Unfortunately, Case 4 had only rare moments when they moved toward consolidation. Their project write-up demonstrated considerable fragmentation. They stated that their objective was to make learning of Shakespeare more meaningful than the traditional teacher-directed approach. In examining their project, it became evident that their main struggle throughout this study was not knowing how to operationalize that goal using Web resources. They ended up including three categories of Web resources: (a) numerous sites about Shakespeare's life and times; (b) sites for criticism; (c) sites for chat rooms about his works. The main requirement for their students would be to develop a Web page that included excerpts from an (unspecified) play translated into modern language along and other information of their choice about Shakespeare. The purpose of each of the tasks implied by the resources was not clear, nor were the relationships among the resources and the tasks made clear. Additionally, two of the three resource categories were for information on Shakespeare that could be found in one or two books.

Successful Consolidation and Integration of Project ideas, Project Requirements, and Information Sources. Unlike Cases 3 and 4, Case 1 (Jack, Jane, & Jill) demonstrated considerable consolidation early on in the work on their project. They chose a travel-related topic that would require students to use the Web primarily to gather extensive information to plan a vacation itinerary. Once they identified a specific sub-topic (e.g., car rental rates), they searched for Web sites consistent with the topic, then noted the URL. When consolidating ideas and available resources, they often discounted options or simplified the structure and scope of their project to keep it manageable. For instance, when grappling with the question of student autonomy in choosing vacation destinations, Jill said "so do we want to leave it completely up to them, or give them a scenario such as you're going to California?" Jack replied, "It might be easier to say you're going to California." Jill went on to explain, "it would be easier on them, but also on us, because we would know what were are looking for in grading this." She explained to one of the instructors that "verifying" students' work would require such structure. Although the group failed to consider varied notions of teaching that would entail alternative evaluation techniques in this instance, they did move toward further consolidation.

Their project write-up also showed evidence of consolidation. They wrote that the purpose of their project was to involve students in an authentic learning task that would require them to integrate their knowledge of geography, math, language arts, etc. to plan a vacation using the Internet. Students would choose from three vacation planing scenarios that stipulated the state, the total budget, time frame, and number of family members. Students would have to use those constraints to plan: how they will get there; where they will stay; what/where they will eat; how they will get around; and what they will do for entertainment. They identified three categories of web sites for their students to use: (a) mapping; (b) travel agencies; and (c) state tourist information. They clearly articulated how these categories would be needed. The plan was to help their students get started with a few good sites, then turn it over to them.

The extent to which participants were successful consolidating the web resources into a coherent project was largely dependent on whether or not their metacognitive processing involved articulation of a project goal and monitoring of search progress in light of that goal. Although Tammy and Kara (Case 2) took longer than Jack et al.

(Case 1) to articulate their final project goal, they were just as successful in developing a coherent project. Case 2 needed to engage in more negotiation of what the project would entail since Kara was inclined toward direct teaching methods while Tammy was in favor of creating a more student- directed, open learning environment. This negotiation process seemed to encourage their consolidation processing.

The written report developed by Case 2 provided strong evidence for a coherent project. Interestingly, Tammy and Kara included the fewest number of web resources. In addition to the EduStock site, they anticipated their students would want to access the financial profiles of favorite companies and might want to explore an on-line Investment Club to get a feel for the language used by investors. Much of the information their students would need was available within the EduStock site. It provided some general information on the stock market, allowed for monitoring the performance of companies on the stock market, and included a program for simulating investment in companies one chooses. Although Case 2's project would require the least amount of web searching for future students, relative to the projects of the other three cases, it clearly would require the highest level of cognitive effort and complex problem solving on the part of their future students.

Conclusions

The study uncovered several prominent findings with implications for understanding how learners generate and evolve project ideas while using the Web. All students were able to generate a project in an open-ended, problem-based environment using an information technology. Although they experienced some difficulty and frustration during the process, they nonetheless all achieved adequate success to meet their course requirements and they all developed in their sophistication of using the Web. Yet, three findings are particularly noteworthy.

First, learners needed to move beyond data-driven processes and become more goal driven in order to efficiently progress toward a coherent project idea. All groups experienced difficulty in the process of consolidating their web project ideas with class project requirements and with the vast number of accessed web resources and tools. However, learners who identified specific goals and project ideas up front, and then used the web to find resources consistent with the identified activity, achieved more coherence. Participants whose final projects did not reflect substantial coherence tended to rely on data driven strategies and rarely evaluated how web resources fit into their project idea. The protocols from the two more successful cases showed constant monitoring of the fit between resources located and the intent of the project. Even while the intent of the project was still evolving, Case 1 and 2 participants were simultaneously evaluating the web resources and the current project idea.

Second, all learners went through several iterations of integrating ideas and accessed web sites in an attempt to stabilize the overall project idea. The process required learners to step back and integrate the activity that will be posed to their students, clarify the reasons for their decisions, evaluate them in light of project requirements, and determine how use of the web fits into the process. This was a difficult process for learners, and they occasionally experienced frustration and confusion as a result. This is at least in part due to the fact that most students had difficulty recognizing limitations in their thinking about how to use and conceptualize the Web as a tool for learning. In addition, many students seemed motivated to protect their initial conceptions of both learning and the Web, despite ongoing evidence that their searching was not leading toward clarification of their projects.

Third, all three sources of knowledge were essential for project development that was both efficient and free of frustration. Metacognitive knowledge was especially important for consolidation processing and often seemed dependent on the system and domain knowledge. Only one case seemed to be able to compensate for a lack of system and domain knowledge through their use of metacognitive knowledge. This implies that increased instructional scaffolding will be necessary for students using the Web in situations where they are novices in regard to the system and the domain being studied. Future research should examine how instructional scaffolding might encourage more goal driven and metacognitive processing in open learning environments that involve the Web. Our results suggest that such scaffolding may enable students to achieve greater coherency and experience less frustration.

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